High energy electron beam lithography on self-assembled monolayer of 3-aminopropyltriethoxysilane

Class project, EE290b

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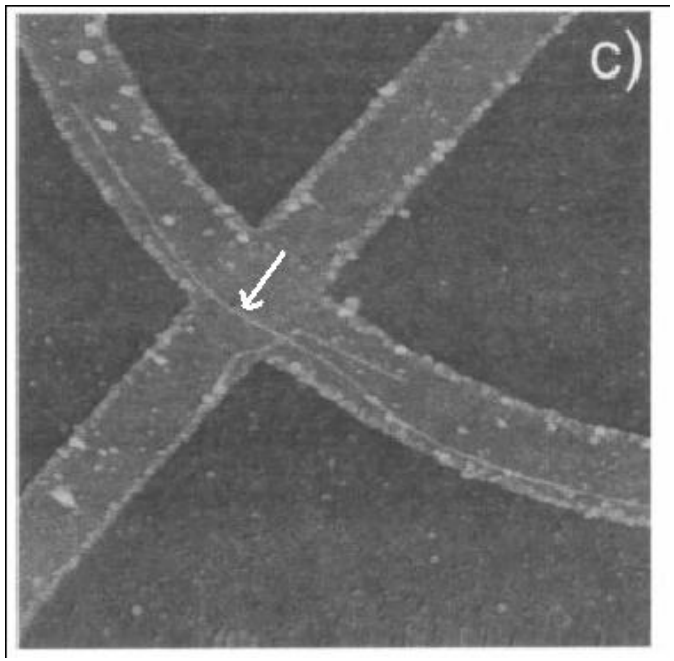
Carbon nanotubes

- Carbon nanotubes (CNT) is a promising candidate for electronic application:
  - Higher current
  - Higher gain
- Diameter of CNT is about 1 to 5 nm
  - How to manipulate?

Self assembly of nanotubes

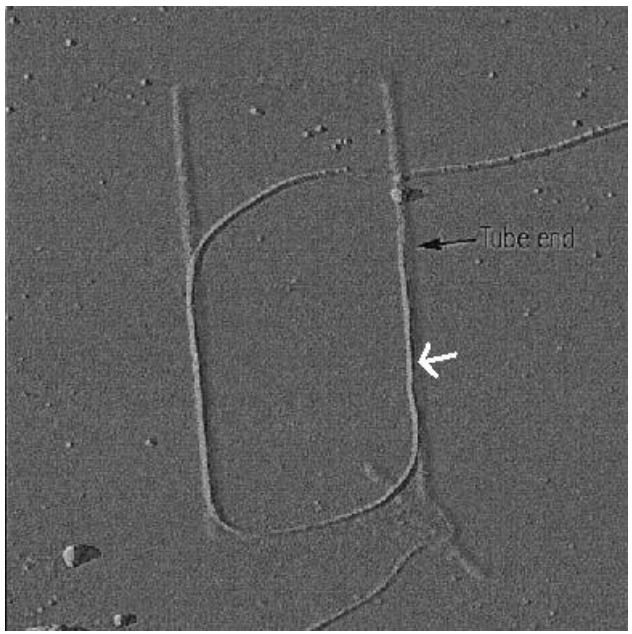
- Nanotubes can be deposited selectively on a patterned substrate of functionalized with amines



K.H. Choi, Surf. Sci. 462 (2000) 195–202

Self-assembly of nanotubes

- CNT selectively adheres to hydrophilic surface

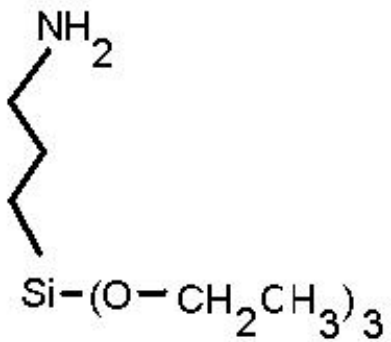


- Direct patterning of trimethylsilane monolayer, followed by deposition of 3-aminopropyltriethoxysilane (APTES)

J. Liu et al, Chem. Phys. Lett. 303 1999 125–129

Direct patterning of APTES

- 3-aminopropyltriethoxysilane:

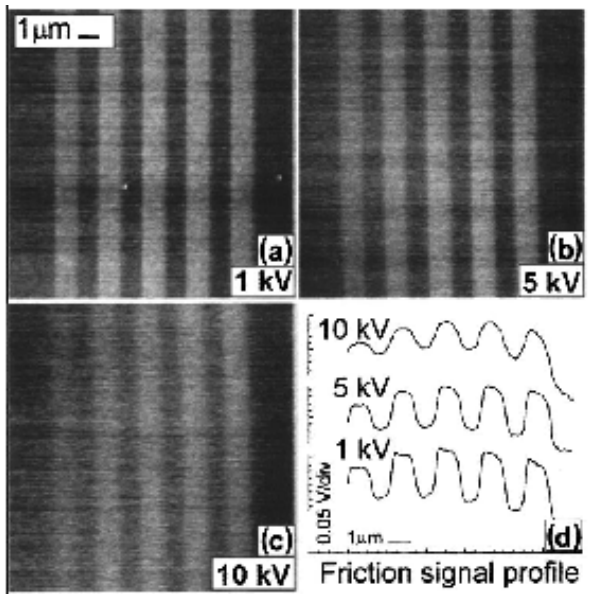


- Silane binds to silicon oxide surface
- NH_2 binds to the nanotubes

- E-beam: destroys the amine groups

Previous results

- Patterning at low voltages (1keV) is feasible



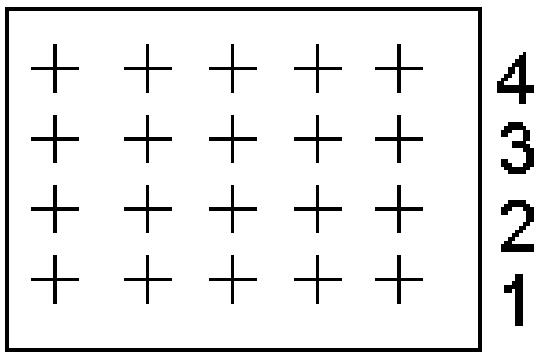
Dose ~ 100 μC / cm^2

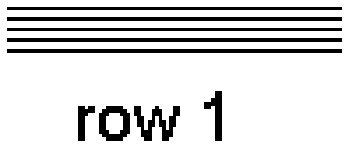
Harnett et al, Appl. Phys. Lett., Vol. 76, No. 17, 24 April 2000

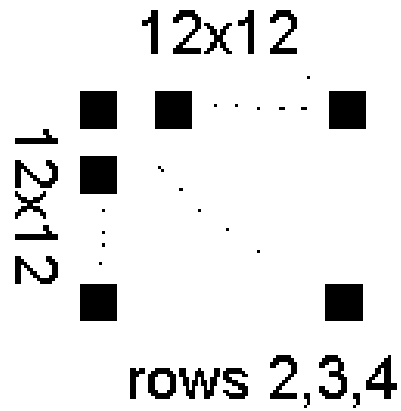
This work

- Pattern APTES using 100keV electron beam
- Dose = 1000 to 10000 $\mu C/cm^2$
- Make very small features on APTES to see how alignment of CNT may be improved

Layout



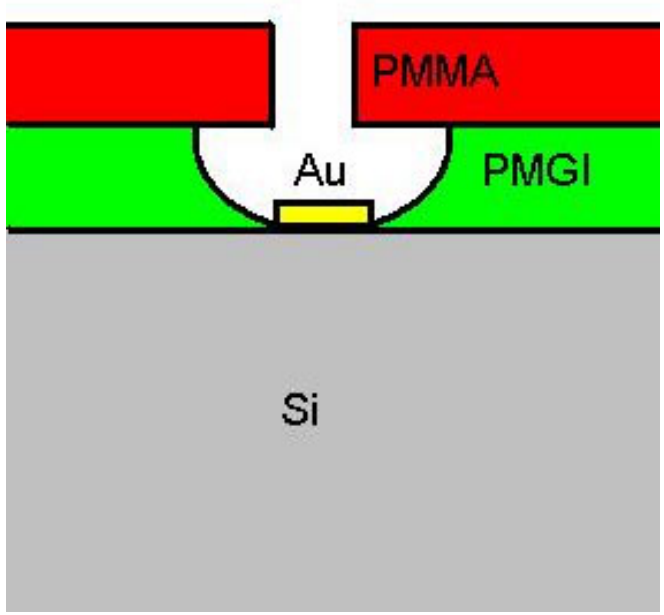




- Row 1: 100 nm lines and spaces
- Rows 2 to 4: 12 x 12 squares, from 100nm to 10nm

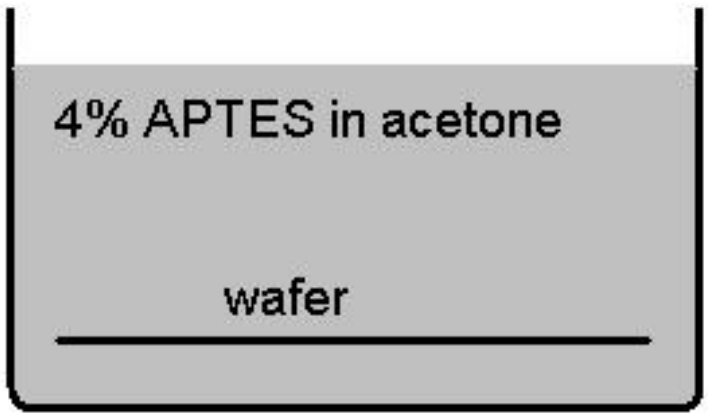
Process Flow – step 1

- Patterning of Cr/Au alignment marks by lift-off



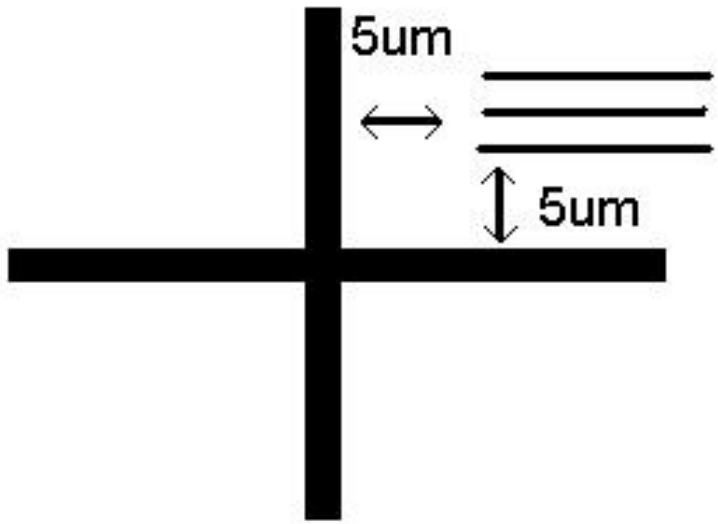
Process flow – step 2

- Oxygen plasma cleaning
- Deposition of APTES monolayer: standard recipe in molecular biology



Process flow – step 3

- Monolayer patterning: align to markers and expose patterns (5 um, 5 um) relative to the center of cross.

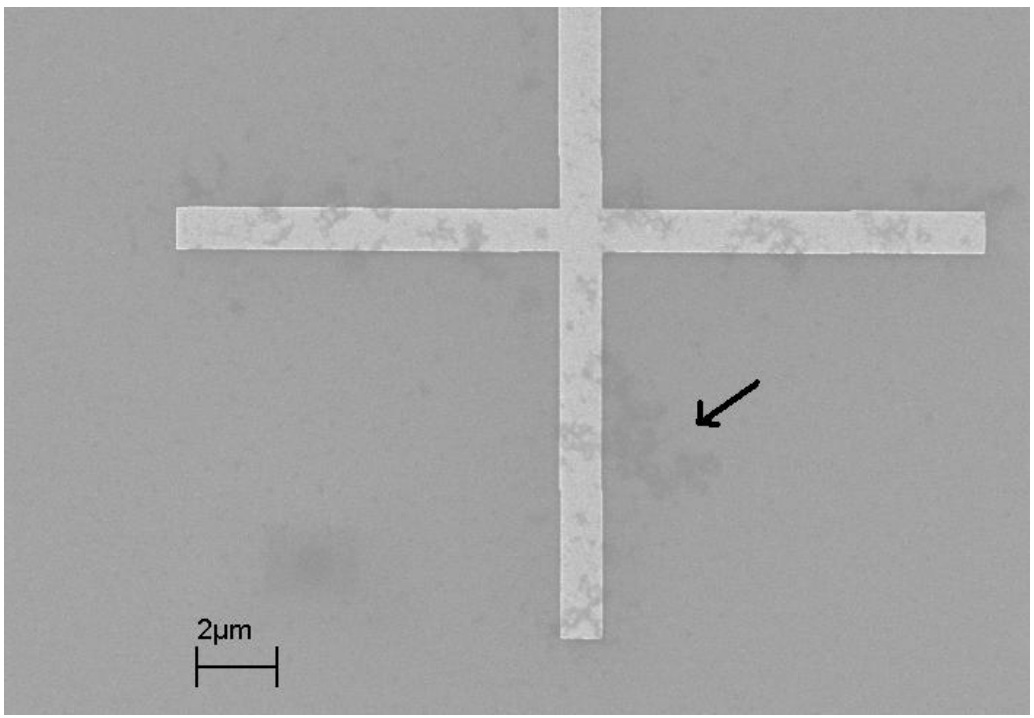


Characterization

- Tapping mode AFM
- Functionalized gold particles with citrate groups: selective adhesion to amines.

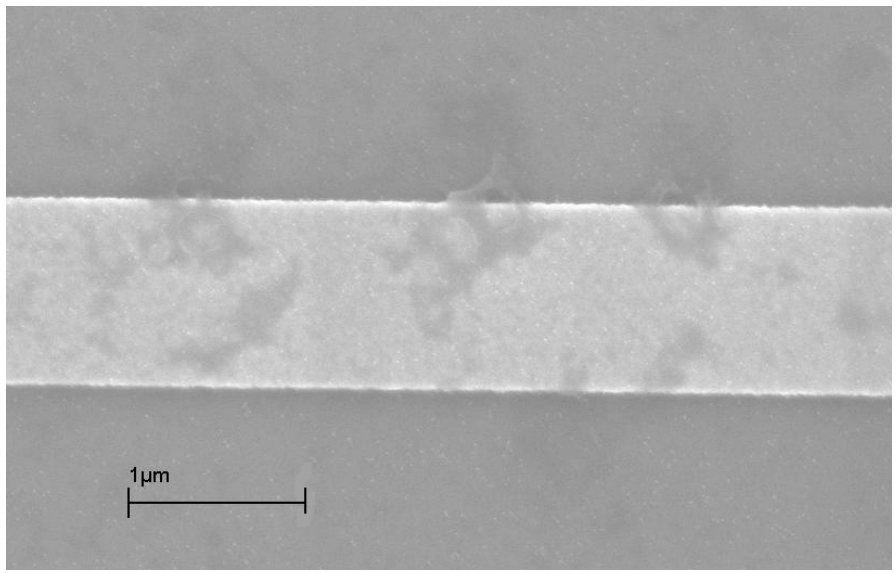
SEM results

- Non-uniform surface



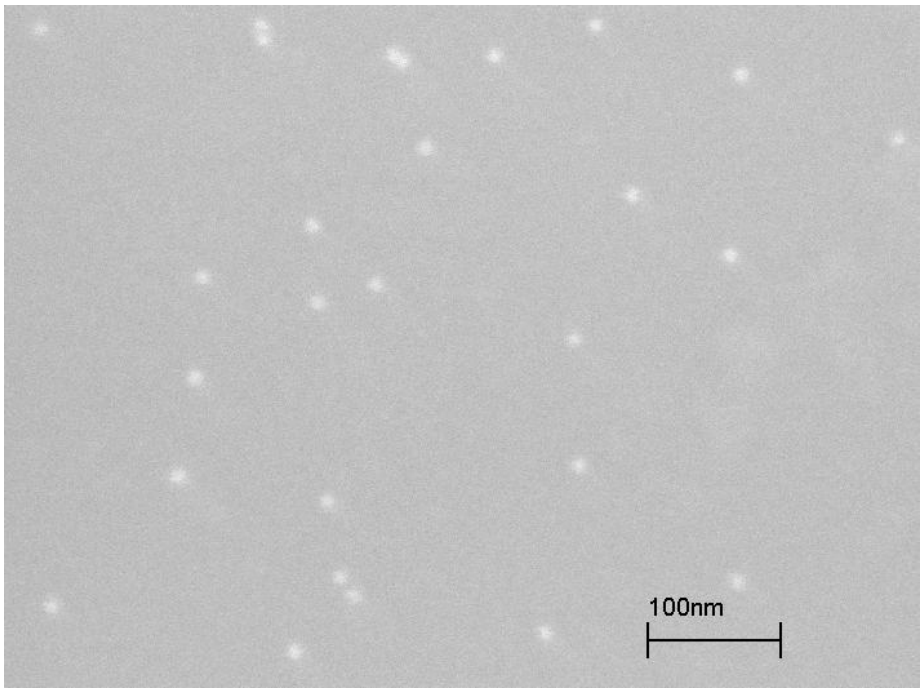
SEM results

- Need improved monolayer deposition



SEM results

- Nanoparticles: density is too low



- Mean spacing is 100nm
- Expected: 10nm, calculated using known concentration and volume used

Nanoparticles

- Mean diameter is 10nm
- To cover a 4” wafer, need ~10^{14} particles
- Used 3ml solution with concentration of $6x10^{12}$ particles / ml. over 20 cm^2

- .:Nanoparticle sticking efficiency seems low

Summary

- Exposure of APTES monolayer at 100keV attempted
- Dose required seems very high
- Characterization is difficult

Future work

- Improve monolayer deposition
- Improve characterization: use particles that stick to exposed surface only
- Contact mode AFM / lateral force microscopy

Acknowledgement

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